EXPERIMENTAL STUDIES ON SEEDLING DEVELOPMENT OF CERRADO WOODY PLANTS

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Abstract

Views of several authors concerning the natural regeneration of the cerrado (Brazilian wooded savanna) are summarized. Except for one, all of them agree that seed germination and seedling growth are disturbed by the harsh environmental conditions that prevail in the savanna. Unfavorable factors that have to be taken into account are dryness at soil surface, rather long drought period, and, above all, fire. Vegetative reproduction, on the other hand, is pointed out by the same writers as the most common means of maintenance and spread of the cerrado; the extent to which the plants set offspring vegetatively seems to be closely related to the degree of disturbance wrought in the cerrado environment by the factors mentioned above. For the study reported in this paper, many plants were grown in Rio de Janeiro (rain forest) zone) and at Paraopeba (cerrado zone), and observed from seed germination. A number of mature trees were also kept under observation in a small cerrado stand located in the Botantical Garden of Rio de Janeiro. A large number of data dealing primarily with seedling development is tabulated, with special reference to the length attained by both the primary root and the shoot at various ages. Data are also included which elucidate the germination features. Evidence is presented which indicates that, up to an age of two years, no taproot succeeds in reaching a depth of 1m. Thus the plantlets are forced to pass through 1-2 drought periods with their roots in the driest portion of the soil. It is recalled that in dry, sunny stations the cell walls are far more lignified and suberized in shoots and roots, and that the root cap cell walls are endowed with pectin, whose water-retaining ability is well-known. Accordingly, the suggestion is made that the real critical period in the establishment of seedlings in dry places is, as a matter of fact, the very early stages of development, when the cell wall devices have not had time yet to attain the necessary degree of completeness. It is suggested that many woody species peculiar to the cerrados would make their best growth if they received some additional water; this seems to mean that the seedlings would require favorable sites to become established in nature, where human disturbance and drought conditions are reduced to a minimum. However, this point must await fresh data from various sources. It has been verified that a number of seedlings can bear the destruction of either the primary root or the shoot; provided they are sufficiently watered, they soon remake the lost parts. Epigeal germination, which is mostly observed in trees, prevails largely over hypogeal germination; this in turn occurs primarily in undershrubs. A number of stowing tissues from underground tuberized organs were analysed for their water content; it ranged from 44 to 91% according to the ligneous or fleshly nature of the parts involved. The role of fire as a destructive agent for both seeds and seedlings is emphasized; insect larvae are also mentioned in this connection.

Introduction

Ferri (1961a) states boldly that: "after many years of studies in cerrados we were struck by the fact that we never found seedlings of permanent plants that we could say with certainty had come from seeds. Vegetative reproduction of various kinds is responsible for the maintenance of this vegetation in a certain place and for its spreading." Ferri (ib.) says further: "Experiments with seeds of *Stryphnodendron adstringens, Dimorphandra mollis, Bombax gracilipes, Kielmeyera coriacea, Annona coriacea, Aspidosperma tomentosum*, etc., have shown that there are no problems for the germination under laboratory conditions. However, the same seeds

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sown in the cerrado germinate very poorly if at all. And even when some germination occurred the final survival of seedlings was extremely low." In another paper (Ferri, 1961b), he states again: "In the well-established cerrados I have never found plantlets of which I could say with certainty that they had come from seeds." Rizzini & Heringer (1962a) claim that: "It is through extensive suckering that the cerrado dwellers manage to survive the *disturbances wrought in their habitats by man,* and even to spread out over newly opened areas. Seeds play an insignificant part in this process, since the conditions existing there bring about serious difficulties to germination as well as keep the seedlings from growing *in most cases.* The great powers of vegetative reproduction those species prove to have account for their *resistance to fire and axe* under the well-known stunted condition." They refer to: "one experiment carried out by the authors at Paraopeba (which) shows that the cerrado plants are in need of more water to develop from seed than they receive from natural sources." This experiment consisted in sowing seeds of *Caryocar brasiliense* Camb. (Piqui) in cerrado soil with, as well as without, irrigation; for the next 10 months, irrigated seeds germinated freely, and seedling growth was excellent. Their concluding statement is as follows: "In fact, the savannas referred to display seed-born young plants only in especially favorable spots, where some moist, shaded depression exists."

Accordingly, the same investigators (ib.) record an instance of seedlings developing spontaneously when they write in reference to *Stryphnodendron barbatimao* Mart. ". . . however, we succeeded in finding young plants of various ages in nature." Some other instances have been found more recently of young plants from seed growing in protected sites in the cerrado. It should be noted that Rizzini & Heringer (ib.) insist on the fact, of great moment, that: "underground structures for vegetative propagation are also very peculiar to the *disturbed* savanna vegetation." Again: ". . . as for the regeneration out of seeds at later ages—this mainly in the usual *heavily disturbed status.* It is notorious that the putting in action of such a process depends especially upon *trauma.*"

It is quite evident that the more disturbed a cerrado is, the more intense is the vegetative reproduction it displays. Well-grown cerrados, and *cerradões* (forests made up of characteristic cerrado species bearing straight trunks), as recognized by a number of workers, constitute a *mesic environment* in which seeds do germinate and seedling growth takes place rather abundantly. In another paper the same authors (1962b) while referring to the shrubby storey in the *cerradão,* state that: "There is a large number of young plants produced by the extant trees."

Labouriau *et al.* (1963) assembled some data which seem at first sight to indicate that germination, and seedling growth, do take place normally in the cerrados. But one cannot avoid pointing out that the instances reported by them are too meager to clarify the issue involved in the natural regeneration of the Brazilian savanna, and that the cerrado in which their observations were carried out was well-developed showing a dense ground cover of herbs and shrubs; this keeps the soil surface in good condition of shelter for germination. In this connection, it is to be noted that the germinating seeds and plantlets *(Dalbergia violacea, Caryocar brasiliense,* and *Aspidosperma verbascifolium)* of Labouriau and his co-workers were located "around a big tree" and "under a big tree," viz., at sheltered spots. The month, February, was, too, one of the most favorable ones since it is situated farther in the rainy season.

More recently, Rizzini (1964) has again commented on the point asserting

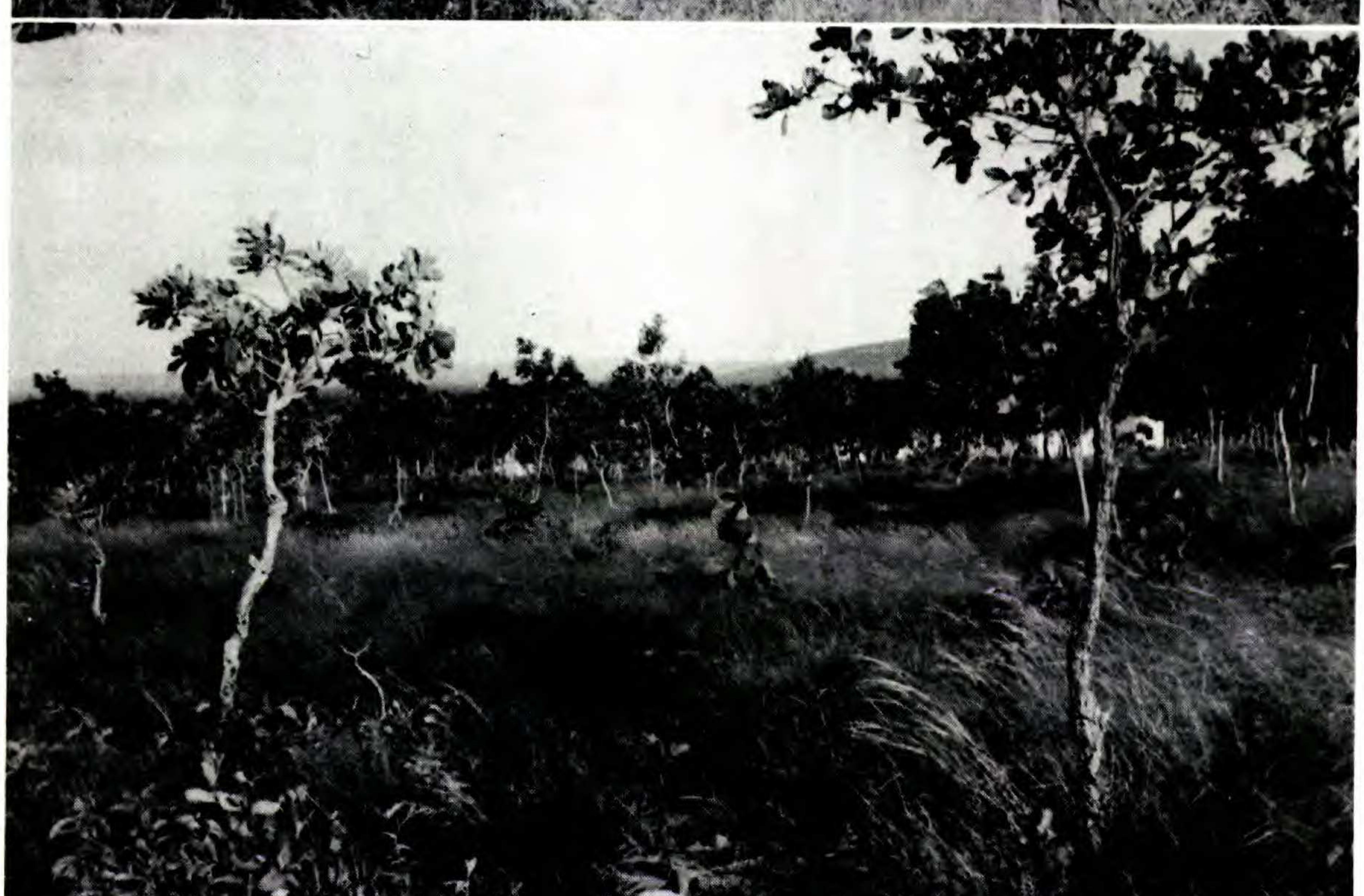

Fig. 1 (top). Closed, preserved cerrado at Varzea da Palma (Minas Gerais). Note the crooked treelets and the low grass cover. Photographed at the end of the rainy period. Fig. 2 (bottom). Open, touched cerrado at Varzea da Palma (Minas Gerais). Besides the crooked, small trees, note the grass cover taller than in Fig. 1. Photographed at the end of the rainy period.

once more that new plants arisen from seed are found but rarely in the cerrados.

L. Osse (1964), in devising a scheme designed to the recovery of extensive cerradoes for charcoal production, considered their regeneration by means of vegetative reproduction through gemmiferous roots as the sole workable one. He did not rely upon seeds, as he declares plainly. His standpoint may be instanced as follows (version): "In fact, the likelihood that a seed will come to germinate, and that the resulting seedling will grow up to be a tree, has been looked on as far scant in view of the environmental harshness, though highly tolerant species have been taken into account."

Among the earlier authors who treated this issue, Warming (1892) remarked that: "seeds, fruits, and young small plants are very easily destroyed by fire or killed by heat." But further on (ib.) he postulated that while seed-born herbs are seldom found in the cerrado, the major part of the adult trees come from seed. Finally, it must be recalled that, according to Warming (ib.), as early as 1835, Lund regarded propagation by seed in the cerrados as a mere exception.

Still more important in any case is to verify whether the plantlets originating from seed will in fact become established in the habitat *to a significant extent;* that a few of them succeed in doing so, the present writer, and others, have ascertained.

As neither of these discrepant views may be looked upon as a definitely acceptable explanation, it will generally be agreed that the point must remain open to new data from research work on several related fields. For instance, many more *in natura* observations are badly needed; Labouriau and his colleagues themselves appeal to everyone interested in the biology of the cerrados to undertake such observations. Also Warming has left the question open to further, more reliable information.

This paper is intended to contribute some data on the early development of a number of cerrado woody species, from seed germination, under culture conditions. No doubt, such data will bear upon the afore said point. It is hoped, before all else, that the present study regarding the growth of the primary root during the time that covers the drought period (i.e., the first 4-7 months) will help, when more data of other sorts are available, to determine whether the young plants come from seed can, or cannot, become established on a grand scale in the cerrados (wooded savannas which clothe most of the Brazilian Central Plateau over more than 1,500,00 square kilometers, and stretch as far south as Paraná and as far north as Amazonas; see Fig. 1 & 2).

Materials and Methods

The seeds were collected at different localities in the States of Minas Gerais and Goias by the author and by Dr. Ezechias P. Heringer, whose help the writer wishes to acknowledge. A number of visits to the extensive cerrado area which extends over those tracts were made for this purpose.

Two sets of cultures were carried out, one by the author in Rio de Janeiro, under a climate of rain forest, and the other at Paraopeba (Minas Gerais), under cerrado climate, by Dr. Inael M. da Silva, to whom the present writer is indebted for a number of important data.

The Rio de Janeiro cultures were undertaken as follows. If not otherwise stated, the seeds were sown in cans filled with coarse brown sand derived from the *restinga* (this is a type of sclerophyll forest or scrub of medium size stretching over the Quaternary sandy plains lying beside the sea). This kind of sand contains some 47 mg % of nitrogen, and has shown itself to be the best substratum for cerrado woody plants, at least in youth. Although the cans were left outdoors, receiving both rain water and full sunlight, additional water was supplied whenever necessary. It was observed that some seedlings wither when the temperature at sunlight reaches 44C; *Vochysia thyrsoidea* Pohl even gets somewhat scorched, but recovers. The seedlings, too, died if permitted to dry up.

Only a few specimens were obtained in the Botanical Garden of Rio de Janeiro from beds prepared for the purpose in clayey soil derived from gneiss.

It should be mentioned that *Dimorphandra mollis* Benth. was able to stand

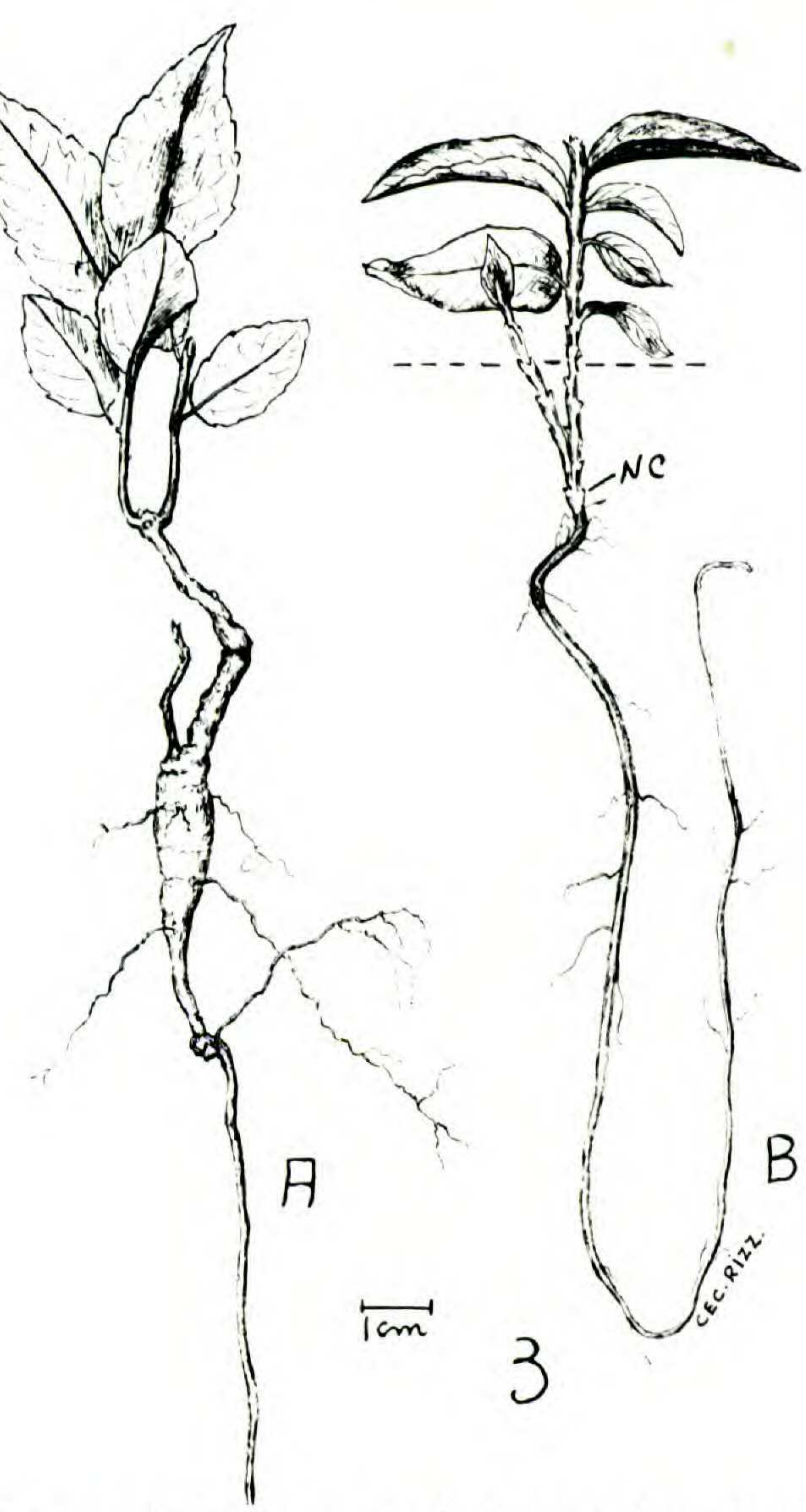

Fig. 3. A: *Plenckia populnea* Reiss., woody hypocotylar tubercle about 3 years old obtained from nature; note dead base of a previous shoot. B: *Parinarium obtusifolium* Hook. at the 7th month; note 2 shoots with underground basis.

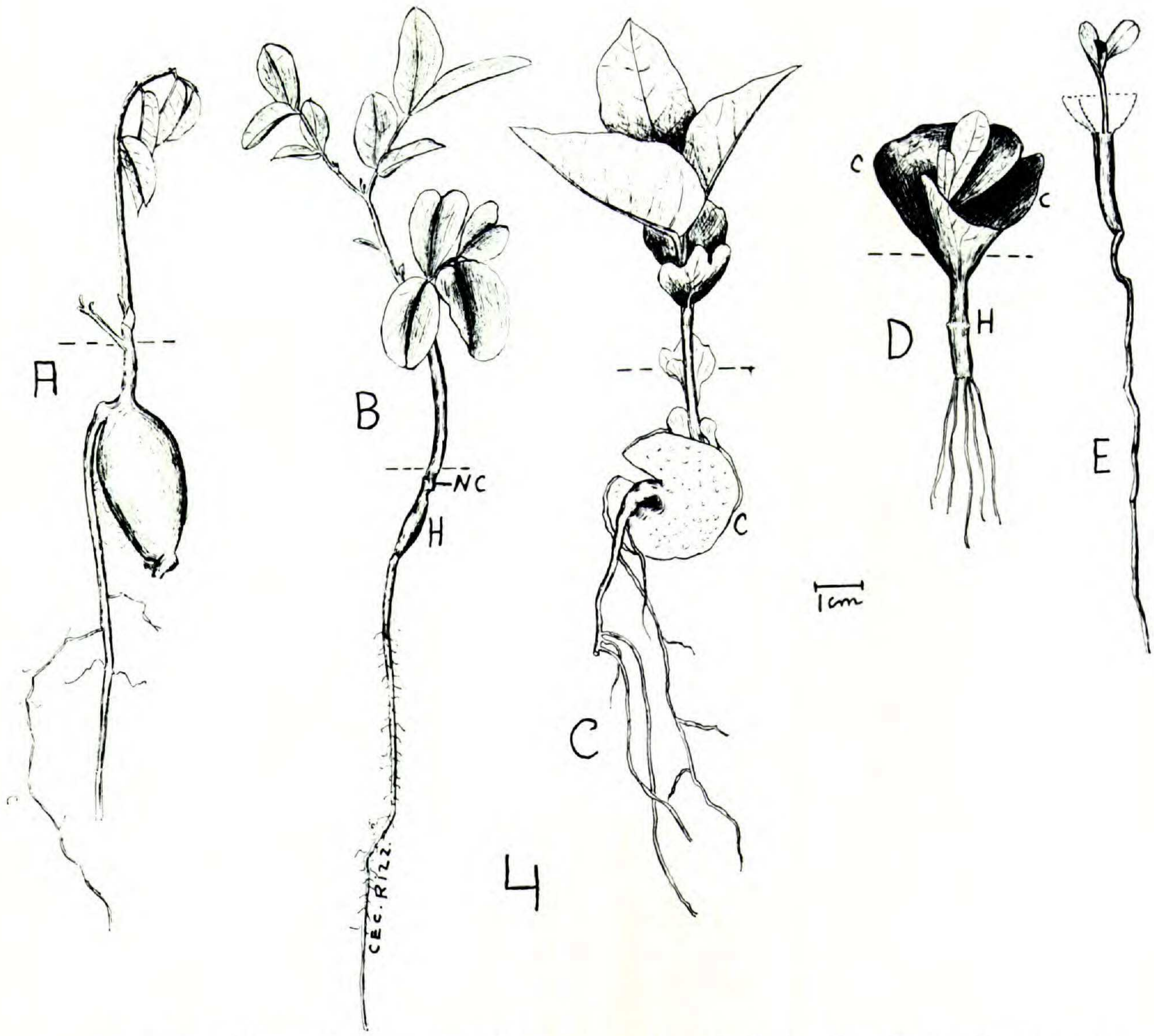

Fig. 4. Seedlings of various cerrado woody species. A: *Andira humilis* Benth., 1 month old. B: *Copaifera oblongifolia* Mart., 45 days old; note slightly thickened hypocotyl. C: *Aspidosperma verbascifolium* M.-Arg., 1 month old with large, rounded cotyledons; observe some long secondary roots arising from the remaining upper portion of the primary root which was cut off; lower leaves are lobate. D: *Vochysia thyrsoidea* Pohl, 2.5 months old showing large cotyledons in the middle of which lies the exceedingly small shoot; note several adventitious rootlets arising from the hypocotylar basis in place of the primary root which was cut off. E: *Vochysia thyrsoidea* Pohl, 2.5 months old in which the cotyledons were removed to show the poorly developed shoot; note the thick hypocotyl and the slender primary root. C, cotyledon; H, hypocotyl; NC, cotyledonary node.

shading during the early stages of growth. For about 18 months, some individuals were kept in pots in the laboratory without being touched by any sunlight. This is in accordance with the known fact that young plants of such a species live long within the overcast environment of the *cerradão.* The shaded seedlings, however, exhibited poor development in contrast with those living at full exposure.

Another remark of ecological import regards the readiness with which the seedlings can regenerate both the aerial portion and the primary root when these parts are cut off or otherwise destroyed. It is feasible, for example, to uproot the seedling by pulling and, after examination, to replace it in the soil; most of the plants show no sign of any damage. Thus, it is an easy task to transplant the young plants without the usual care this operation requires.

At Paraopeba, Dr. Inael prepared several beds in the very cerrado soil, in which he sowed a large amount of seeds gathered from many cerrado trees. Thus, germination and the early development of his plants were conducted at full exposure; but some other plantlets proceeded from the nursery, and were transplanted with care so as not to injure their primary root.

Some other data from Paraopeba, however, come from earlier experiments by Dr. Ezechias P. Heringer, the well-known cerrado researcher. Still other data from this locality were assembled by the present writer during various sojourns there; they refer almost exclusively to plants cultivated under shelter in the nursery. Paraopeba has a well-defined dry season usually lasting some 6 months, which was compensated by irrigation of the experimental beds.

Seedling Development

As an introductory remark, one should point out that, with very few exceptions, trees and shrubs thriving in the cerrado exhibit deep taproots. At an early age, a number of species present a thickened central organ either composed from the hypocotyl or more often from the primary root (Fig. 3A); they are tuberized, short, drought-resistant, root systems. Most species, however, possess long, rather slender taproots from the beginning of development (Fig. 3B, 5). Exceptions to these rules are *Thieleodoxa lanceolata* (Hook.) Cham. and *Casearia sylvestris* Sw., both of which are originally small forest trees; their root systems, for a number of months, proved to be poorly developed, tiny, and slow-growing (Fig. 5D).

Vochysia thyrsoidea Pohl, a conspicuous representative of the cerrado woody flora, also departs from the normal pattern of development. Seeds thereof only germinate at the soil surface, emitting two cotyledons which grow large (2-3 cm in length) as well as succulent and fleshy; the hypocotyl, which appears at the same time, is thick, watery, and prolonged downwards by a slender primary root. The cotyledons are the assimilatory organs of the seedling for no leaves arise at this stage. The shoot, bearing foliage leaves, scarcely starts to grow out by the third month; the first two leaves are very minute and remain for a long time (at least one year) between the cotyledons; yet the taproot keeps on growing, reaching about 12 cm by the third month (Fig. 4, D & E).

In some species, among the most common ones in cerrado, the taproot is given off and develops for months before the stem meristem of the embryo starts its growth. In such instances there arises a long root from the seed without any shoot. Only when the root attains some 15-30 cm does the above-ground portion commence to emerge. This has been observed in *Andira laurifolia* Benth., *Pouteria torta* (Mart.) Radlk., and *Annona crassiflora* Mart. The same phenomenon was previously reported by Gentry (1952) in *Simmondsia chilensis* (Link) Schne. (jojoba), from Mexican deserts; its seeds send down a root 30-45 cm in length before the shoot arises. In these and other species the cotyledons remain unchanged for more than 2 years inside the seed-shell, in the ground.

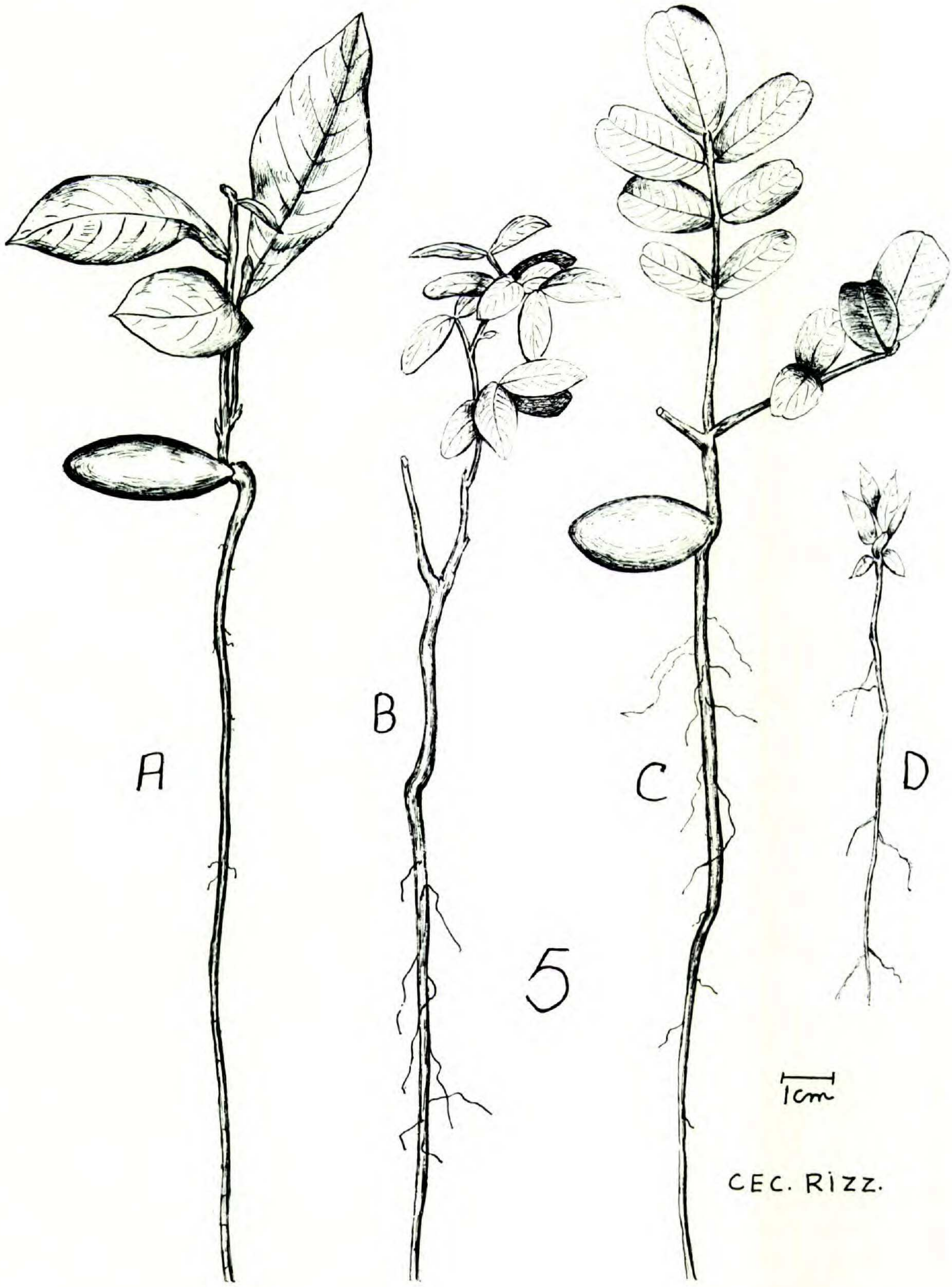

Fig. 5. Plantlets of some cerrado woody species. A: *Pouteria torta* Mart., at the 9th month. B: *Copaifera oblongifolia* Mart., at the 10th month. C: *Andira humilis* Benth., at the 7th month. D: *Thieleodoxa lanceolata* (Hook.) Cham., at the 4th month; note the short primary root.

Table 1. Data from species grown in Rio de Janeiro in *restinga* coarse brown sand.

Species	Age months	Root cm	Shoot cm	Germinat. type	Germinat. time	Germinat. %
Peschiera affinis (M.-Agr.) Miers var. *campestris* Rizz., *Apocynaceae*	2	15	7	epig.	90-127 d	75
Terminalia argentea Mart. & Zucc., *Combretaceae*	2	12	16	epig.	47 d	15
Spiranthera odoratissima St.-Hil., *Rutaceae*	2	11	4	hypog.	45-62 d	28
Hancornia speciosa Gomez, *Apocynaceae*	3	12	8	epig.	30 d	—
Mimosa clausenii Benth., *Leguminosae*	3,5	13	7	epig.	6-10 d	100
Thieleodoxa lanceolata (Hook.) Cham., *Rubiaceae*	4	8	3	epig.	65-80 d	10
Casearia sylvestris Sw. var. *lingua* Eichl. f. *campestris* Eichl., *Flacourtiaceae*	4	8	3	epig.	40-60 d	20
Cassia mystacicarpa Rizz. & Her., *Leguminosae*	5	12	9-12	epig.	11-18 d	100
Dimorphandra mollis Benth., *Leguminosae*	5	25	14	epig.	3-7 d[a]	100
Andira humilis, A. laurifolia Benth., *Leguminosae*	5-9	25-35	5-12	hypog.	32 d-8 m	66
Annona crassiflora Mart., *Annonaceae*	6	30	8	epig.	7–10 m	75
Esenbeckia pumila Engl., *Rutaceae*	6	15	3	hypog.	28-35 d	40
Mimosa laticifera Rizz. & Mattos, *Leguminosae*	7	20	90	epig.	6-10 d	100
Parinarium obtusifolium Hook., *Rosaceae*	7	31	3	hypog.	6 m	25
Chrysophyllum soboliferum Rizz., *Sapotaceae*	7	15	only leaves	hypog.	34-62 d	90
Erythrina mulungu Mart., *Leguminosae*	8	16	10	epig.	30 d	90
Anemopaegma arvense (Vell.) Stell., *Bignoniaceae*	8,5	22	10	hypog.	14-23 d	90
Astronium fraxinifolium Schott, *Anacardiaceae*	9	30	6	—	—	—
Enterolobium ellipticum Benth., *Leguminosae*	9	75	30	epig.	3 d[a]	80
Platypodium elegans Vog., *Leguminosae*	9	22	15	hypog.	—	15
Magonia pubescens St.-Hil., *Sapindaceae*	9	30	6-10	hypog.	20-40 d	50
Pouteria torta Mart., *Sapotaceae*	9	40	5-6	hypog.	37-90 d	100
Vochysia thyrsoidea Pohl, *Vochysiaceae*	9,5	25	3	epig.	40 d	60
Copaifera oblongifolia Mart., *Leguminosae*	10	25	6	hypog. or semi-epig.	20-35 d	58
Sclerolobium aureum Benth., *S. paniculatum* Benth., *Leguminosae*	10	15-25	10	epig.	12 d	40-60
Stryphnodendron confertum Her. & Rizz., *Leguminosae*	13	26–30	3-4	epig.	9-11 d	50

[a] Oven.

Observations—A few seeds of *Andira* and *Pouteria* required respectively 8 and 6 months to germinate. Some seeds were placed to germinate in a moist chamber at 30 C. In *Peschiera affinis* the primary root is 30 cm long by the 8th month.

Table 2. Data from species raised at Paraopeba in cerrado soil.

Species	Age, days	Root, cm	Germinat. time	Germinat. %	Root at 12 m
Astronium fraxinifolium Schott (forest)	103	26	17 d	90	50 cm
Astronium urundeuva (Fr. All.) Engl.	129	14	9 d	90	47
Dimorphandra mollis Benth.	106	12	19 d	30	—
Terminalia argentea Mart. & Zucc.	81	29	33-39 d	70	34
Piptadenia macrocarpa Benth.	88	44	4-5 d	80	—
Mimosa laticifera Rizz. & Mattos	117	16	13 d	90	98
Plathymenia foliolosa Benth. (forest)	126	20	8 d	80	65
Plathymenia reticulata Benth.	90	11	17 d	50	18
Bowdichia virgilioides H. B. K.	102	23	33 d	40	—
Dipteryx alata Vog.	23	16	12 d	90	31
Magonia pubescens St.-Hil.	35	17	11 d	70	28
Caryocar brasiliense Camb.	47	20	73 d	50	—
Piptadenia communis Benth. (forest)	78	24	7 d	90	53

Observation—Magonia pubescens, in Rio de Janeiro at age 1 month shows a taproot 10-12 cm long; other data in Table 1.

A summary of the most important results concerning the bulk of the species investigated in Rio de Janeiro is presented in Table 1. The following features were taken into account:

1. Age of the seedlings in months.
2. Length of the primary root in centimeters.
3. Height of the primary shoot in centimeters.
4. Germination type, whether epigeal or hypogeal.
5. The time germination takes, in days or in months, to send up either the cotyledons (epigeal germination) or the plumule (hypogeal germination).
6. Percentage of germination.

The data from cultivation of some cerrado species at Paracopeba are listed in Table 2, which includes also a few forest species for the sake of comparison. These data were provided by Dr. Inael M. da Silva. The features considered were the following:

1. Age of the seedlings in days.
2. Length of the primary root in centimeters.
3. Time consumed by germination in days.
4. Percentage of germination.
5. Length attained by the taproot at one year; in this case, the 12 month period was counted from the day on which the seedlings were transplanted from the nursery to the cerrado beds; the seedlings were already 2-6 months old when taken into the open.

Table 3 presents some additional data obtained years before from old cultures by Dr. Ezechias P. Heringer as well as some others drawn from Rizzini & Heringer (1962a). Although they are rather miscellaneous, they may have a bearing upon the problem of cerrado regeneration.

As may be seen from the tables, none of the plant species thriving in the cerrado, over one year (one drought period), has succeeded in sinking its taproot into the ever-wet portion of the soil, that is, below 1 m. Table 3 shows plainly that, after two years, several of them have not yet attained this depth even in cerrado surroundings. In the instance of two species, one from forest, the other from savanna—*Astronium fraxinifolium* and *A. urundeuva*, *Plathymenia foliolosa* and *P. reticulata*—the cerrado entities seem to be at a disadvantage as to the rate growth of the primary root, under the same conditions for both species.

Figure 5 illustrates four such species grown in Rio de Janeiro at early stages of development. It is to be noticed that the primary root is far longer than the first shoot, which is remarkable for its slow rate of growth. Seedlings are shown in Fig. 4.

Leaf Change

The majority of the seedlings held in culture in the moist climate of Rio de Janeiro, and receiving additional water whenever the weather is sunny, do not shed their leaves during the months which comprise the cerrado dry season, namely, from May to September. Instead they produce new leaves mostly in October, though they may sometimes do so as early as September; by November they exhibit

Table 3. Miscellaneous data from species cultivated at Paraopeba in cerrado soil, combined with other data drawn from Rizzini & Heringer (1962a).

Species	Age, months	Root, cm	Shoot, cm
Anemopaegma arvense (Vell.) Stell.	6	30	9
Caryocar brasiliense Camb.	10	80	40
Dalbergia violacea (Vog). Malme	12	32-37	10-22
Hymenaea stigonocarpa Mart.	12	45	34
Kielmeyera coriacea (Spr.) Mart.	12	23–35	7–8
Erythrina mulungu Mart.	24	15	8
Sclerolobium aureum Benth.	24	85	13
Anacardium pumilum St.-Hil.	27	80	15
Hancornia speciosa Gomez	24	60	40
Kielmeyera corymbosa (Spr.) Mart.	24	40	12
Ouratea sp.	24	30–40	2–5
Stryphnodendron barbatimao Mart.	24	40	20
Sweetia lentiscifolia (Schott) Spr.	24	40	14
Plenckia populnea Reiss.	24	4–9	2–5

Observation—*A. arvense* and *A. pumpilum* are undershrubs, though the latter grows into a tree in the genial climate of Rio de Janeiro reproducing by seed from typical undershrub plants.

their fresh small leaves. Thus, the replacement of the old leaves by the new ones proceeds gradually, the former standing rather long together with the latter. The following account describes the behavior shown by some species.

Mimosa multipinna Benth., *Peschiera affinis* (M.-Arg.) Miers var. *campestris* Rizz., *Pouteria torta* Mart., *Chrysophyllum soboliferum* Rizz., *Sclerolobium paniculatum* Benth., *Andira laurifolia* Benth., *A. humilis* Benth., *Copaifera oblongifolia* Mart., *Thieleodoxa lanceolata* (Hook.) Cham., *Vochysia thyrsoidea* Pohl, and *Dimorphandra mollis* Benth., have been observed to emit new leaves from October to November, the earlier ones still remaining and being shed little by little; these leaves can even last for a number of months after they are one year old.

Decidedly deciduous species are far less numerous; they loose their leaves under any climate, as *Esenbeckia pumila* Engl., *Stryphnodendron confertum* Her. & Rizz., *Erythrina mulungu Mart.*, and *Bombax* sp. They become leafless about June. The leaves gradually turn yellow before falling off and the falling itself is also gradual. *Annona crassiflora* Mart. deserves special mention for it sheds its leaves almost altogether; however, the new ones begin to burst as early as September when there are still one or other of the old leaves left.

Fresh shoots are also laid down at the same time, almost always from the cotyledonary node which lies at the stem basis; in most plants this part is hidden beneath the ground surface. Adventitious reparative buds can, too, be easily formed there.

In the Botanical Garden of Rio de Janeiro there is a small cerrado stand some 30 years old. The savanna trees do very well in the humid climate and clayey soil which prevail there, as Fig. 6 and 7 illustrate. Due to such a climate, the grass cover, composed of grasses not peculiar to the cerrado, attains great development, keeping green the year round.

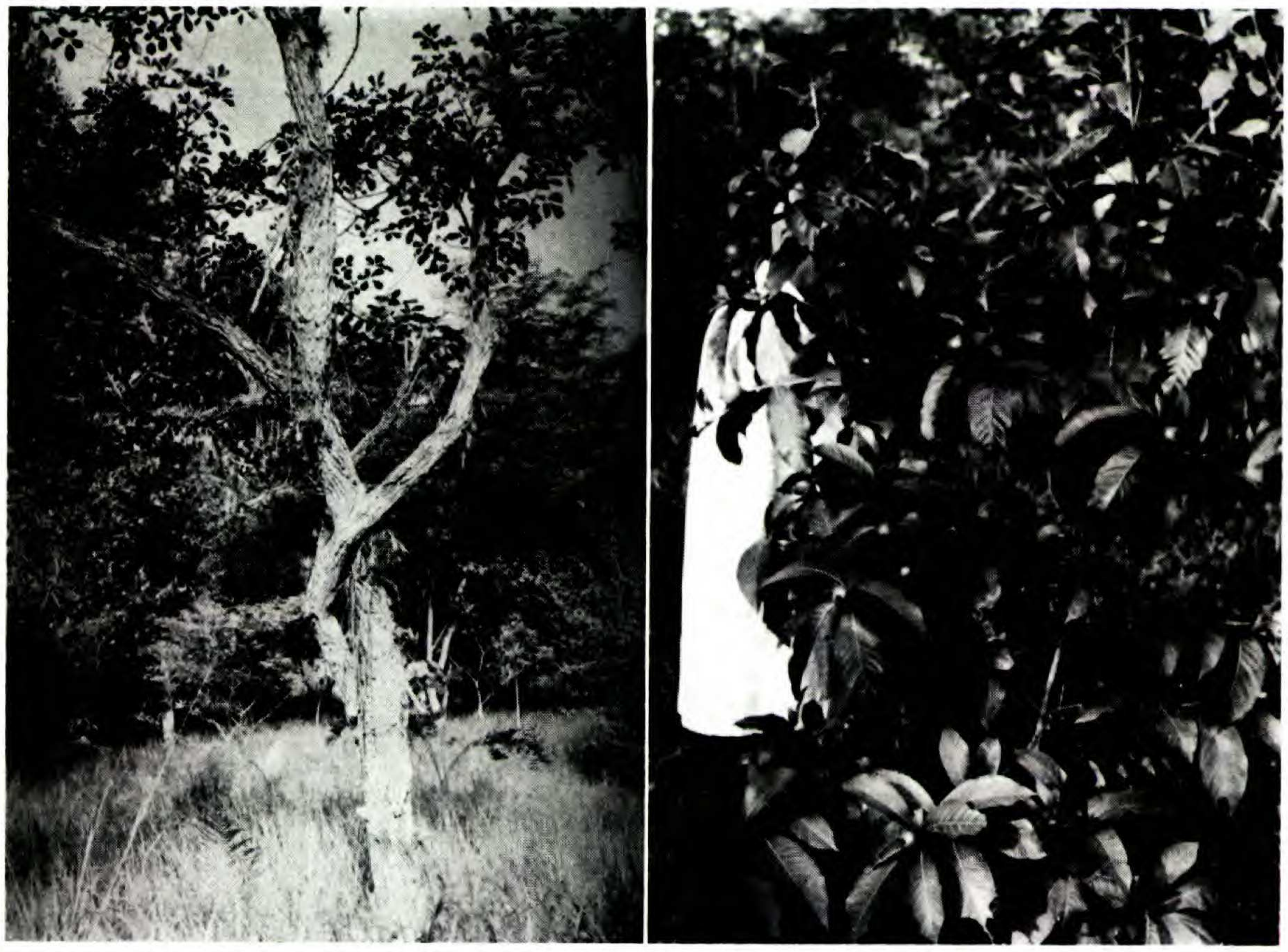

Fig. 6-7. Cerrado stands at the Botanical Garden of Rio de Janeiro. Fig. 6 (left) illustrating in the foreground *Tabebuia ochracea* Cham. displaying corky bark; notice the grass cover. Fig. 7 (right) illustrating *Thieleodoxa lanceolata* (Hook.) Cham. in fruit.

In such a man-made cerrado it is noted that new leaves are set out between October and November. *Copaifera langsdorffii* Desf., *Sweetia dasycarpa* (Vog.) Benth., *Hymenaea stigonocarpa* Mart., *Caryocar brasiliense* Camb., *Lafoensia sp.*, *Tabebuia ochracea* Cham., *T. alba* Cham., *T. caraiba* (Mart.) Bur., *Fagara sp.*, *Anacardium humile* St.-Hil., *Plathymenia reticulata* Benth., *Thieleodoxa lanceolata* (Hook.) Cham., *Diospyros sericea* DC., and so on, were seen to behave as has just been referred to above. For an account of the cerrado flora the reader must see Warming's (1892) classical work and Rizzini's (1963) modern one.

These facts, together with others mentioned before (see Introduction), seem to suggest that the woody plants peculiar to the cerrados appreciate increased humidity.

Naturally occurring cerrados never become entirely leafless, although the shedding of leaves is intense. The leaves fall off gradually in the course of the drought period, but not altogether, and the new leaves start to spring as soon as the rains come or even before their coming. This means that, as is generally admitted, the soil water reserves are just sufficient to maintain the savanna in a state of reduced life activity; accordingly, a number of species either blossom or set fruit during the dry season. It is interesting to notice that the development of fresh leaves occurs simultaneously both in Rio de Janeiro and in the cerrado, i.e., mostly in October at the two areas.

The worst hindrance to vital processes in the cerrado is the fire annually set by cattlemen and by farmers, which sweeps the savannas on a gigantic scale the wide world over. Fire cannot fail to have a profoundly harmful influence on such a vegetation like the cerrado which is richly supplied with dried, easily burning remains during several months. The reader is referred to Warming (ib.) for details on this point; he notes, for instance, that fire burns the leaves and hastens the leaf-fall.

Cerrado and cerrado plants in Rio de Janeiro may be said to be far greener than they are in their natural surroundings.

Water Stored in the Underground Parts

It was decided to measure the amount of water the plants possessing thick, tuberized, subterranean organs are able to reserve in their tissues. This was accomplished in a number of cases. Pieces of these organs were placed in fully corked vials and brought to the laboratory. After their weight was estimated, the pieces were dessicated at 100C and weighed again. The amount of water is presented as percentage of the fresh weight. The plant tissues used were taken from nature unless otherwise stated. Some species from other kinds of vegetations besides the cerrado were included for comparison.

Corytholoma discolor (Lindl.) Frits., fleshy aerial tubercle from rain forest, gathered in April	90%
Cochlospermum sp. from Pernambuco, fleshy root from culture in Rio de Janeiro	85%
Cissus simsiana R. & S., root tubercle from cultivated plants	82%
Mandevilla illustris (Vell.) Woods., tuberous root	72%
Marsdenia virgultorum (Fourn.) Rothe, from limestone, fleshy root collected in July	65%
Annona crassiflora Mart., hypocotylar tubercle with fleshy cortex, 3 months old, from culture	60%
Plenckia populnea Reiss, hypocotylar ligneous tubercle with thick, soft cortex	59%
Chrysophyllum soboliferum Rizz., underground shoot (subole) with thick, soft cortex	57%
Manihot gracilis M.-Arg., fleshy, starchy root	57%
Terminalia argentea Mart. & Zucc., woody root tubercle from nursery	56%
Piptadenia macrocarpa Benth., the same as above	48%
Piptadenia falcata Benth., woody root tubercle	44%

There follow four additional results from Rachid (1947).

Craniolaria integrifolia Cham., big fleshy root	up to 91%
Ipomoea villosa Meissn., tubercle	80%
Manihot tripartita M.-Arg., root tubercle	87%
Cochlospermum regium (Mart. & Schr.) Pilg., fleshy root	75%

Had the dry weight been taken into consideration, the water percentage, for example in the tubercles of *Corytholoma discolor,* would amount to 876% instead of 90%.

Comments

The data so far obtained seem to indicate that no taproot goes down below 1 m at an age of 1-2 years or, putting it differently, young plants must survive at least 1-2 drought periods with their main root placed in the driest part of the soil (the rainless season in the cerrado commonly lasts 6 months, and is characterized by a very clear sky). At first glance *Caryocar brasiliense* would be a possible exception, according to the data in Table 3; however, the plants from which the measures were taken were copiously irrigated ones (see Rizzini & Heringer, 1962a).

That roots of many plant species can survive soil dryness well beyond the wilting point is obvious from observations in arid and semi-arid countries and, according to some authors, roots can even grow in dry soil. Even conifers may be cited in this connection. Stone (1958) mentions that seedlings of *Pinus ponderosa*, *Libocedrus decurrens*, and *Abies concolor* can stand, respectively, 64, 44, and 35 days in a soil devoid of any available water. Moreover, he points out that application of artificial dew during night to such plantlets suffices to keep them alive for 30, 72, and 20 days more, while the soil remains in the same waterless condition. Thus, the three species can bear a period of water shortage in the soil embracing about 2-3-4 months, at least under experimental conditions. Conifers are interesting in this concern because they carry a number of "xerophytic" devices though they do not live in dry habitats in the usual sense.

The present writer found that in a well-developed dry forest at Sete Lagoas (Minas Gerais) a rather abundant regeneration of plants of *Hymenaea stilbocarpa* Mart. preserved their leaves in a good condition in the middle of the dry season. One of these young plants, about 1 year old, bore a primary root some 30 cm long, yet the soil around it carried only 7% water, certainly below the wilting point.

Keeping in mind such considerations, it is desirable to direct attention to the means through which relatively slender roots will be able to go through a rainless period sunk in a dry substratum.

The ability of roots to endure soil dryness in countries possessing a drought period may well be connected to the precocious as well as far more intense *lignification and suberization* that are known to take place in both roots and shoots of plants thriving under dry, sunny conditions (Warming, 1909, who gives a full account of this subject, which is sharply commented and enlarged on by Milanez, 1951; Killian & Lemée, 1956). These cell wall modifications represent efficient devices against drought and heat effects. A further, no less important fact to recall is the *deposition of pectin* in the walls of the root cap cells. As is known, pectin is a highly water-holding substance which is apt to keep the root growing point in a good state of turgescence preventing it from dessecating, despite the dryness of the medium. It is to be pointed out that heavy lignification and suberization are quite well-known in the savannas, macchia, cerrado, campo, and other areas.

The above considerations seem definitely to displace the problem of the establishment in dry habitats to the *very early stages of seedling development*—when the cell wall contrivances have not yet attained full development and consequently the young plants are not able to withstand drought. It follows that the *real critical period would be the first drought season* to be passed through by the seedlings, subsequent to seed germination. Thus the data afforded by this paper on the length of the primary root of cerrado plants, in the course of such period, may help in solving the issue when other data are available.

The critical point is to ascertain (a) whether the seeds can in fact germinate, and (b) whether the minute seedlings can bear the harsh conditions of soil and drought that prevail in the environment of most cerrados. Ferri (1961a), as mentioned earlier in this paper, claims plainly that both cannot: "And when some germination occurred the final survival of seedlings was extremely low." Under milder conditions, such as those reported in this paper, they developed quite well. Rizzini & Heringer (1962a) think that the swift growth the taproot possessed at early stages in many such seedlings would "enable the plants to withstand the drought period with the absorbing part of the roots sink into the ever-wet portion of the ground *wherever the spot be favorable.*" But the same authors (ib.) remark that such a spot "rarely occurs in the *far touched cerrados,* which is exactly the type found in the most parte of their range."

It may be said that the rate growth of the primary root, whether in Rio de Janeiro or at Paraopeba, is about equal. In the few cases in which a comparison was possible in the same species (*Magonia, Terminalia, Anemopaegma*), the cerrado-grown ones showed a slightly better rate of growth.

One cannot leave out a consideration of the role that fire, so wide-spread in the cerrados, most probably plays in the destruction of seedlings. Seeds, too, are liable to perish by fire (Warming, 1892; Rizzini, 1964). Ferri (1961a) as well as Rizzini (ib.) draw attention to the high degree at which seeds are destroyed in cerrado by insect larvae.

Of no less importance is to take into due consideration the *high powers of regeneration* the seedlings proved to have, after serious traumas, when well watered. Under the heading of MATERIALS AND METHODS this peculiar property has already been referred to. Attention should be drawn to the fact that the regeneration ability shown by seedlings is in accordance with the sprouting ability of the corresponding adult plants, which set forth coppice shoots freely from both aerial stumps and even underground portions, not to mention their normal yearly sprouting from the branches. The role played by this outstanding feature in the seedling stage has not yet been ascertained in regard to the establishment of the plants in their habitat.

Germination features also deserve some comment. Table 1 shows that the epigeal type of germination predominates largely over the hypogeal one. In broad terms, the epigeal type belongs to trees (exceptions are only *S. confertum* and *P. affinis,* undershrubs), while the hypogeal type is typical of six morphologically very similar undershrubby species, though they are quite unrelated from a taxonomic viewpoint (exceptions are only the trees *P. elegans, M. pubescens, and P. torta*). *C. oblongifolia* is transitional between the two groups; although most of its seedlings exhibit underground cotyledons, some send them up into the air. The voluminous seeds of *Caryocar brasiliense* (not included in Table 1) germinate hypogeally.

Among the plants of the hypogeal group excel large-seeded species. Nevertheless, *S. odoratissima, E. pumila,* and *P. elegans* belong here and they have decidedly small seeds.

The seeds of *Annona crassiflora* rank first in regard to the amount of time they require to germinate for, although not especially hard-shelled, they consume as much as 7-10 months. Next to them rank the seeds of the *Andirae.* However, in these species the seeds are not enclosed in a shell as hard as that of *Parinarium obtusifolium*, whose seeds take about 6 months to germinate.

Finally, species provided with water-storing underground structures at early stages, though obviously present, do not make up the bulk of the flora. The major part thereof displays long, slender taproots.

This is not the right place to draw definitive ecological implications from the data assembled here for they evidently need to be tied to data of other sorts.

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